

Consolidated Laser Ranging Data Format (CRD)

Version 1.00

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27 June 2008

Revision History

0. Revision Summary

- v 0.25 12 February 2007 - Initial public release
- v 0.26 12 March 2007 - Update based on community input
- v 0.27 15 November 2007 - Further updates based on community input

0.1 0.25 – 12 February 2007

- First public release

0.2 0.26 – 12 March 2007

- Added sample files
- Added “Common Abbreviations” and “Resources” sections

0.3 0.27 – 15 November 2007

- Added revision history.
- Added target type to target header H3.
- Added data quality alert to station header H4.
- Refined clock offset fields in the transponder configuration record C4.
- Added "stop number" to ranging record (10).
- Added “origin of values” to meteorological record (20).
- Clarified use of terms “time-of-flight” and “range.”
- Revised station file naming conventions in Section 5.
- Other changes for consistency or improved readability.

0.4 1.00 – 27 June 2008

- Clarify handling of free-format character fields
- Clarify handling of H4 record unknown stop time.
- Explicitly state that C1 record pulse length is fwhm.
- The units of epoch delay correction in record C3 have changed to microseconds.
- Record 21 Sky Clarity suggested format has changed from integer to floating.
- Add detector channel to '40' calibration record and '11' normal point record.
- Expand “data type” in '40' calibration record to handle 1 and 2 way calibrations.
- Add more sample data sets, including all possible records.
- Add table showing which records correspond with which data types.
- Note that 3.0 has already been subtracted from kurtosis.
- Explain 'fullrate, fire only' files (.frf) for one-way transponders.
- Explain possibility of using '30' pointing angles as fundamental measurements (3.6.2).
- Converted old section 7 and 8 to appendices A and B and inserted sections 7-9.
- Change normal point window length (record '11') from integer to floating point.

Abstract

Due to recent technology changes, the existing International Laser Ranging Service (ILRS) formats for exchange of the 3 laser ranging data types - fullrate, sampled engineering and normal point - are in need of revision. The main technology drivers are the increased use of kilohertz firing-rate lasers which make the fullrate data format cumbersome, and anticipated transponder missions, especially the Lunar Reconnaissance Orbiter (LRO), for which various field sizes are either too small or non-existent. Rather than patching the existing format, a new flexible format encompassing the 3 data types and anticipated target types has been created. This change in formats provides the opportunity to include fields and features that were desired but not available in the old formats.

Introduction

The purpose of the Consolidated Laser Ranging Data Format (CRD) is to provide a flexible, extensible format for the ILRS fullrate, sampled engineering, and normal point data. The primary motivations for creating a new format at this time is to allow for transponder data, and to handle high-repetition-rate laser data without unnecessary redundancy. This format is based on the same features found in the ILRS Consolidated Prediction Format (CPF), including separate header and data record types assembled in a building block fashion as required for a particular target.

There are 3 separate sections to the data format: 1) the header section which contains data on the such topics as station, target, and start time; 2) the configuration section containing an expanded version of data previously described by the System Configuration Indicator (SCI) and system CHange Indicator (SCH) fields; and 3) the data section containing laser transmit and receive times, and other highly dynamic information. The data headers are fixed format and similar in content to those of the CPF files. The configuration and data records are free format with spaces between entries. Records can be added as needed for the specific data types and at frequencies commensurate with the data rate. For example, at a 2 kHz ranging rate, meteorological data and pointing angles are commonly read far less frequently than the ranges. Note that 1 way out-bound, 1 way in-bound, and 2 way ranges could all appear within one file. Also note that multiple colors could appear in one file.

Advantages of this format over the current ILRS formats are as follows;

- Flexibility. The data files can be simple and compact for kiloHertz ranging or comprehensive for more complex data structures, as appropriate.

- The building block structure with multiple record type allows for including and omitting certain records types as needed by a station or target.

- Configuration descriptions are addressed in a more explicit, logical and extensible manner than the current format.

- A single integrated format can be used for current and future data and target types.

- Multiple color data, multiple ranging modes (transponder one- and two-way ranges) and multiple configurations can be included naturally within a single data file.

- The format can be expanded in the future as needs expand without abandoning the entire format.

- All data types (full rate, sampled engineering, and normal point) can be managed in a single file if desired, e.g., for archival and reference purposes.

Extensibility to the eXtensible Markup Language (XML) is provided for in the design.

Fields in the Configuration sections are compatible with the SLR Engineering Data File (EDF) format.

When data is converted from an old format to the CRD format, there will be fields (such as skew and kurtosis) that do not exist in the old format. In these cases, unless noted otherwise, numerical fields in the new format should be set to “-1” to indicate “no information”. Character fields without information should be filled with “na” for “Not_Available”.

In the following pages, sections 1 – 3 provide a description and discussion of the specific file sections and record types. Following that, section 4 gives examples of the file structure for various types of data. Section 5 addresses file naming conventions. Section 6 provides some real-world examples of the new format, while section 7 provides information about implementing and testing the CRD format on site. Section 8 was included to provide a quick overview of the new data fields and their use. Appendix A provides web references to formats and “official lists” as well as links to CRD test data sets and sample code containing format converters and CRD file check programs. Finally, Appendix B provides definitions of abbreviations.

1. Header Records

Fields in header records are defined according to the following **FIXED FORMAT** specifications (in contrast to data records which will have free format fields that are delimited by white space). Upper and lower case characters are both acceptable: e.g., "H1" or "h1"; "CRD" or "crd" in H1.

White spaces are allowed (where appropriate) in header record fields since these are fixed format.

1.1.Format Header

The format header describes information relating to the file: e.g. the version of the format used, time of production etc.

1.1.1.Format:

1-2	A2	Record Type (= "H1" or "h1")
4-6	A3	"CRD" or "crd" (Consolidated Ranging Data format)
8-9	I2	Format Version
11-14	I4	Year of file production
16-17	I2	Month of file production
19-20	I2	Day of file production
22-23	I2	Hour of file production (UTC)

1.1.2.Notes

There must be one and only one format header record in the file and it must be the first record. Format version will be 1 for version 1.00 – 1.99, 2 for 2.00-2.99, etc. All changes between n.00 and n.99 must be backward compatible. This means no new fields will be added between existing fields, etc. New fields could be added to the end of a record or additional record types could be added.

1.2.Station Header

The station header describes information relating to the station or site collecting this laser data.

1.2.1.Format:

1-2	A2	Record Type (= "H2" or "h2")
4-13	A10	Station name from official list (e.g., "MOB7 ", "MLRS ")
15-18	I4	Crustal Dynamics Project Pad Identifier
20-21	I2	Crustal Dynamics Project 2-digit system number
23-24	I2	Crustal Dynamics Project 2-digit occupancy sequence number
26-27	I2	Station Epoch Time Scale - indicates the time scale reference. 3 = UTC (USNO)

4 = UTC (GPS)

7 = UTC (BIH)

1-2, 5-6, 8-9 = reserved for compatibility with earlier data using obsolete time scales.

10 and above = UTC (Station Time Scales)

1.2.2. Notes

For station-created files, there must be one and only one station header record in the file and it must be the second record. Data centers may combine files.

The “Station Time Scales” option is needed to describe the time scale that accommodates the added precision of fire and return times for transponder ranging. The other time scales are not (yet) good to 1 picosecond, so some other ad hoc time scale must be used. Since the time scale techniques will evolve with time, there are many indicators (10-99) available to describe which time scale is used. In fact, these indicators may be station or experiment dependent.

The Crustal Dynamics Project Pad, site, and occupancy sequence number are often combined into the “CDDIS SOD” found in the official pad and code list mentioned in the introduction to this document.

1.3. Target Header

The target header describes static information relating to the target, whether it is a satellite, lunar or spacecraft target.

1.3.1. Format:

1-2	A2	Record Type (= "H3" or "h3")
4-13	A10	Target name from official list (e.g., "Ajisai", "GPS35")
15-22	I8	ILRS Satellite Identifier (Based on COSPAR ID)
24-27	I4	SIC (Satellite Identification Code)
29-36	I8	NORAD ID
38-38	I1	Spacecraft Epoch Time Scale (transponders only) 0 = Not used. 1 = UTC 2 = Spacecraft Time Scale
40-40	I1	Target type 1=passive (retro-reflector) artificial satellite 2=passive (retro-reflector) lunar reflector 3=synchronous transponder 4=asynchronous transponder

1.3.2. Notes

There must be at least one target header (and associated child records) in a file but there could possibly be more, e.g. for accumulating normal point data for many targets over a period (e.g. one day) for transmission to data centers.

COSPAR ID to ILRS Satellite Identification Algorithm:

COSPAR ID Format: (YYYY-XXXA)

YYYY is the four digit year of when the launch vehicle was put in orbit

XXX is the sequential launch vehicle number for that year

A is the alpha numeric sequence number within a launch

Example: LAGEOS-1 COSPAR ID is **1976-039A**

Explanation: LAGEOS-1 launch vehicle was placed in orbit in 1976; was the 39th launch in that year; and LAGEOS-1 was the first object injected into orbit from this launch.

ILRS Satellite Identification Format: (YYXXXAA), based on the COSPAR ID

Where YY is the two digit year of when the launch vehicle was put in orbit

Where XXX is the sequential launch vehicle number for that year

AA is the numeric sequence number within a launch

Example: LAGEOS-1 ILRS Satellite ID is **7603901**

1.4. Session (Pass) Header

The session/pass header describes information relating to the period over which the data is collected. For normal satellite targets this is generally each pass, but could be associated with pass segments. For geostationary satellites and distant targets, it must be related to time segments as defined by the station. It will be necessary to specify and hence enforce that certain parameters or conditions remain constant or static during a session.

The session header is the place to indicate what type of data records follow – this will enforce data records to be provided in blocks of consistent data rather than allowing sampled engineering, full rate and normal point records to be randomly intermingled.

Hence there must be a Session Header preceding each block of data and there may be more than one Session Header for a given pass or segment if different types of data follow.

1.4.1. Format:

1-2 A2 Record Type (= "H4" or "h4")

4-5 I2 Data type

0 = full rate

1 = normal point

2 = sampled engineering

7-10 I4 Starting Year

12-13 I2 Starting Month

15-16	I2	Starting Day
18-19	I2	Starting Hour (UTC)
21-22	I2	Starting Minute (UTC)
24-25	I2	Starting Second (UTC)
27-30	I4	Ending Year (Set ending date and time fields to “-1” if not available.)
32-33	I2	Ending Month
35-36	I2	Ending Day
38-39	I2	Ending Hour (UTC)
41-42	I2	Ending Minute (UTC)
44-45	I2	Ending Second (UTC)
47-48	I2	A flag to indicate the data release: 0: first release of data 1: first replacement release of the data, 2: second replacement release, etc
50-50	I1	Tropospheric refraction correction applied indicator 0 = False (not applied) 1 = True (applied)
52-52	I1	Center of mass correction applied indicator 0 = False (not applied) 1 = True (applied)
54-54	I1	Receive amplitude correction applied indicator 0 = False (not applied) 1 = True (applied)
56-56	I1	Station system delay applied indicator 0 = False (not applied) 1 = True (applied)
58-58	I1	Spacecraft system delay applied (transponders) indicator 0 = False (not applied) 1 = True (applied)
60-60	I1	Range type indicator 0 = No ranges (i.e. transmit time only) 1 = 1 way ranging 2 = 2 way ranging 3 = Receive times only 4 = Mixed (for real-time data recording, and combination of 1- and 2-way

ranging, e.g. T2L2)

Important: If Range type indicator is **not** set to two-way (2) or mixed (4), all corrections must be written as one way quantities. Specifically, this applies to range, calibration, refraction correction, center of mass correction, as well as all RMS and other statistical fields. With “mixed”, separate range data (10), normal point (11), and calibration (40) records will be needed for one-way and two-way data.

62-62 I1 Data quality alert indicator

0 = good quality; nominal/uncompromised data.

1 = suspect quality; Some concerns that data has been compromised but is still useful and could be used with caution.

2 = poor or unknown quality; test, experimental or compromised data not to be used for scientific purposes.

Note: Details of any data degradation can be included in comment (“00”) records,

1.4.2. Notes

For normal point records, stations generating the file must set the Center of Mass and Refraction Applied flags to false and provide data consistent with these flags. The format however allows data to be provided where normal point data have these corrections applied e.g. for special purpose users or for use by data centers themselves.

Note that several of the indicator fields, such as refraction and center of mass correction have the opposite meaning of corresponding Merit II flags. For instance, in the Merit II fullrate format, center of mass applied is set to 0 if the correction is applied. Here, the flag is set to 1 if the correction is applied.

The station system delay applied indicator is normally set to true for normal points.

Ending time may be cumbersome to compute if data is being written directly into the CRD format in real-time. In this case the ending date and time fields may be filled with “-1”.

1.5. End of Session Footer

1.5.1. Format

1-2 A2 Record Type (= "H8" or "h8")

1.5.2. Notes

Include even if it is immediately followed by end of file footer.

1.6. End of File Footer

1.6.1. Format

1-2 A2 Record Type (= "H9" or "h9")

1.6.2. Notes

If an end-of-file footer is missing the implication is that the file has been truncated and has therefore been corrupted. One response could be to request a retransmission of the file.

2. Configuration Records

Configuration records will hold static data that represents station specific configuration information used while collecting the data stored in this file. **All fields must be separated by spaces, and white spaces are *not* allowed within record fields.** These records are **FREE FORMAT** (except that the record ID must be in columns 1-2) and rely on white spaces for parsing. **The field sizes (e.g., I5, F12.5) are suggestions, and should be sized according to the stations' needs. Character strings can be as short as 1 character and as long as 40 characters. Longer strings should be truncated to 40 character on reading. See example 6.6.**

While detailed configuration records are strongly encouraged and are a vital part of the CRD format, the minimum requirement is a "C0" record containing the Transmit Wavelength and the System Configuration ID, and the "60" Compatibility Record. The "60" record is not required if records C1-C3 are included, although it may be useful until the format is fully implemented. Record "C4" is always required for transponder data.

The "detail type" field in the configuration records allows for future expansion of the configuration record format. At this time, this field will always have the value "0".

2.1. System Configuration Record

The system configuration record provides a means for identifying all significant components of a system in operation during collection of the data records contained within this file. This record will be an extensible list of configuration records of components deemed necessary to characterize the system at any given time during which data records are collected.

2.1.1. Format:

A2(1-2) Record Type (= "C0" or "c0").

I1 Detail Type (= "0").

F10.3 Transmit Wavelength (nanometers)

A4 System Configuration id (unique within the file)

A4 Component A configuration id (e.g. laser configuration id)

A4 Component B configuration id (e.g. detector configuration id)

A4 Component C configuration id (e.g. local timing system configuration id)

A4 Component D configuration id (e.g. transponder configuration id)

Repeat as required.

2.1.2. Notes

The use of configuration records replaces the current SCI and SCH (but not the station site log) files. To access information currently contained in the SCH file, one should use the date and time as a key and extract the information from station site log files which should be maintained to provide such data. The SCI file is totally replaced by the records in the current file.

The Transmit Wavelength represent the wavelength of the laser beam as transmitted to the atmosphere and is thus common to many of the station subsystems. Hence it is included explicitly in this record. One advantage of this is that the association of data records to wavelength used is more direct.

The file *must* contain at least one Configuration Header. If there are multiple system configurations used when generating the data records contained within the file, then there should be multiple system configuration headers in the file. These should appear after the associated component configuration records have all been defined.

A standard enumerated list of components for many of the configuration fields will be maintained at the ILRS web site (<http://ilrs.gsfc.nasa.gov>). This will include, for example, available detector, laser, and timer types.

2.2.Laser Configuration Record

The file should contain at least one Laser Configuration record. If multiple wavelengths are used or there are significant changes to any of the other parameters within the data sets in the file, then there must be appropriate Laser Configuration records for each wavelength or configuration used.

2.2.1.Format:

A2(1-2)	Record Type (= "C1" or "c1").
I1	Detail Type (= "0").
A4	Laser Configuration ID (unique within the file)
A10	Laser Type (e.g. "Nd-Yag")
F10.2	Primary wavelength (nm)
F10.2	Nominal Fire Rate (Hz)
F10.2	Pulse Energy (mJ): record when this fields changes by 10%
F6.1	Pulse Width (FWHM in ps): record when this fields changes by 10%
F5.2	Beam Divergence (arcsec)
I4	Number of pulses in outgoing semi-train

2.2.2.Notes

Note that the primary wavelength is used here, e.g. use 1064 for a Nd-Yag laser even though only 532 is used.

Most fields are expected to be static for a given laser. Pulse energy and width should trigger the writing of a new record whenever they change by 10%.

2.3.Detector Configuration Record

The file should contain at least one Detector Configuration record. If multiple wavelengths are used or there are significant changes to any of the other parameters within the data sets in the file, then there must be an appropriate Detector Configuration record for each wavelength or configuration used.

2.3.1.Format:

A2(1-2)	Record Type (= "C2" or "c2").
I1	Detail Type (= "0").
A4	Detector Configuration id (unique within the file)
A10	Detector Type (e.g., "SPAD", "CSPAD", "MCP", "APD", "GeDiode", ...)
F10.3	Applicable wavelength (nm)
F6.2	Quantum efficiency at applicable wavelength (%).
F5.1	Applied voltage (V)
F5.1	Dark Count (kHz)
A10	Output pulse type (ECL, TTL, photon-dependent, ...)
F5.1	Output pulse width (ps)
F5.2	Spectral Filter (nm)
F5.1	% Transmission of Spectral Filter
F5.1	Spatial Filter (arcsec)
A10	External Signal processing

2.3.2.Notes

Most fields are expected to be static for a given detector. Spatial and spectral filters changes should be recorded when they change by 10% (for continuously variable filters), or whenever they change (for discrete filters). The field "external signal processing" can refer to a particular technique, algorithm, or software program used.

2.4.Timing System Configuration Record

The file should contain at least one station Timing System Configuration record. If multiple timing systems are used, then there must be an appropriate Timing System Configuration record for each system used.

2.4.1.Format:

A2(1-2)	Record Type (= "C3" or "c3").
I1	Detail Type (= "0").
A4	Timing System Configuration id (unique within the file)
A20	Time Source (e.g. "Truetime_XLi", "Truetime_XL-SD", "Datum_9390", "HP_58503A", "TAC", ...)
A20	Frequency Source (e.g. "Truetime_OCXO", "CS-4000",)
A20	Timer (e.g. "MRCs", "SR620", "HP5370B", "Dassault", "Other", ...)
A20	Timer Serial Number (for multiple timers of same model)
F6.1	Epoch delay correction (us).

2.4.2. Notes

Most of the fields in this record should effectively be pointers to items in the Station Log File where associated static data on each device can be found. The epoch delay correction provides a measure of the propagation delay between the Time Source output and the point at which the timing epochs are registered. For example, in some systems, a 1PPS signal is used to latch second boundaries. However there must be some correction applied for the transmission delay between the source of the 1PPS signal and the timer system. The epoch delay correction has been applied to the data; the value here is for reference only.

2.5. Transponder (Clock) Configuration Record

The transponders header describes static information relating to certain transponders

2.5.1. Format:

- A2(1-2) Record Type (= "C4" or "c4").
- I1 Detail Type (= "0").
- A4 Transponder Configuration ID (unique within the file)
- F20.3 Estimated Station UTC offset (nanoseconds)
- F11.2 Estimated Station Oscillator Drift (UTC/station clock) in parts in 10^{15} .
- F20.3 Estimated Transponder UTC offset (nanoseconds)
- F11.2 Estimated Transponder Oscillator Drift (UTC/spacecraft clock) in parts in 10^{15}
- F20.12 Transponder Clock Reference Time (seconds, scaled or unscaled)
- I1 Station clock offset and drift applied indicator
 - 0 = Neither offset nor drift applied
 - 1 = Only offset applied
 - 2 = Only drift applied
 - 3 = Both offset and drift applied
- I1 Spacecraft clock offset and drift applied indicator
 - 0 = Neither offset nor drift applied
 - 1 = Only offset applied
 - 2 = Only drift applied
 - 3 = Both offset and drift applied
- I1 Spacecraft time simplified
 - 0 = False
 - 1 = True

2.5.2. Notes

Note that standard sense used in all time and frequency metrology must be followed, e.g. local station

offset is (UTC – local station).

A transponder configuration record is required only if the target contains a transponder or time transfer equipment.

To convert from spacecraft master clock units and timescale,

$$t_{UTC} = t_{master} + (t_{master} - t_o) * 10^{-15} * \text{Oscillator Drift} + \text{UTC offset}$$

where t_o is Transponder Clock Reference Time, the time at which master clock was calibrated against UTC (somehow), and the UTC offset is (UTC-master) at time t_o .

For the space craft time simplified mode (used for LRO), t_o has already been removed from t_{master} to allow passing of a much smaller number. The Transponder Clock Reference Time field is filled but only used for reference. The equation then becomes

$$t_{UTC} = t_{master} + (t_{master}) * 10^{-15} * \text{Oscillator Drift} + \text{UTC offset}.$$

The conversion for the station clock is analogous.

A new record should be written whenever a field changes value.

3. Data Records

Data records contain non-static data and hence they all will contain a time-stamp field. **All fields *must* be separated by spaces, and white spaces are *not* allowed within data fields.** These records are **FREE FORMAT** (except for record type, which must be in columns 1-2) and rely on white spaces for parsing. **The field sizes for numerics (e.g., I5, F12.5) are suggestions, and should be sized according to the target's needs and the station's precision. Character fields may be as short as 1 character and as long as 40 characters. Longer strings should be truncated to 40 characters on reading. The exception is that the comment record (id = "00") contents can be up to 80 characters and can contain white space.** There will be no unused or undefined fields. See example 6.6.

For ease of use data records should generally be in time sequence. Time assigned to the calibration ("40") and session ("50") records are at the discretion of the station.

3.1. Range Record (*Full rate, Sampled Engineering/Quicklook*)

The full rate range record contains single-shot measurement data. The file will contain blocks of one or more range records corresponding to a consistent data type (full rate, sampled engineering) and system configuration.

3.1.1. Format:

A2(1-2) Record Type (= "10")

F18.12 Seconds of day (typically to 100 ns for SLR/LLR or 1 picosecond for transponder/T2L2). For transponders, station clock correction may be applied.

F18.12 Time of flight in seconds (none, 1-, or 2-way depending on range type indicator); or (for Epoch Event 5) spacecraft receive time in units of the spacecraft master clock, or seconds if "Spacecraft offset and drift applied indicator" is true. Time of flight may be corrected for station system delay; receive time may be corrected for spacecraft system delay and/or clock correction.

A4 System configuration id.

I1 Epoch Event - indicates the time event reference.

Currently, only 1 and 2 are used for laser ranging data.

0 = Ground receive time (at System Reference Point - SRP) (2 way)

1 = Spacecraft bounce time (2 way)

2 = Ground transmit time (at SRP) (2 way)

3 = Spacecraft receive time (1 way)

4 = Spacecraft transmit time (1 way)

5 = Ground transmit time (at SRP) and spacecraft receive time (1 way)

6 = Spacecraft transmit time and ground receive time (at SRP) (1 way)

I1 Filter Flag

0=unknown

1=noise

2=data

I1 Detector channel

0 = not applicable or “all”

1-4 for quadrant

1-n for many channels

I1 Stop number (in multiple-stop system)

0 = not applicable or unknown

1-n = stop number

I5 Receive Amplitude - a positive linear scale value.

3.1.2. Notes

The format allows multiple color data to be included in the same file, with separate normal point statistics, etc.

As noted above, transmit time only, receive time only, 1-way, and 2-way ranges etc. can appear in the same file, to accommodate transponders.

Note that station transmit and receive times are nominally with respect to the system reference point (SRP) which will in many cases be the telescope invariant point. This requires a knowledge of both the transmit delay and receive delay, which is critical for transponder ranging. It is less critical for normal satellite (two-way) ranging since errors in distributing the system delay to these components will cancel.

The full rate data file should include a swathe of data around the station-assessed signal. The filter flag is used to record whether the station processing indicates that a return is signal or noise.

3.2. Range Record (Normal Point)

The normal point range record contains accepted measurement data formed into normal point bins. The file will contain blocks of one or more range records corresponding to a consistent data type and system configuration.

3.2.1. Format:

A2(1-2) Record Type (= "11")

F18.12 Seconds of day (typically to < 100ns for SLR/LLR or <1 ps for transponders). Station clock corrections should be applied for all targets.

F18.12 Time of flight in seconds (none, 1-, or 2-way depending on range type indicator); or (for Epoch Event = 5) spacecraft receive time in units of the spacecraft master clock, or seconds if “Spacecraft offset and drift applied indicator” is true. Time of flight should be corrected for station system delay; receive time may be corrected for spacecraft system delay and/or clock correction.

A4	System configuration id.
I1	Epoch Event - indicates the time event reference. <i>Currently, only 1 and 2 are used for laser ranging data.</i> 0 = Ground receive time (at SRP) (2 way) 1 = Spacecraft bounce time (2 way) 2 = Ground transmit time (at SRP) (2 way) 3 = Spacecraft receive time (1 way) 4 = Spacecraft transmit time (1 way) 5 = Ground transmit time (at SRP) and spacecraft receive time (1 way) 6 = Spacecraft transmit time and ground receive time (at SRP) (1 way)
f6.1	Normal point window length (seconds)
I6	Number of raw ranges (after editing) compressed into the normal point.
F9.1	Bin RMS from the mean of raw accepted time of flight values minus the trend function (ps)
F7.3	Bin skew from the mean of raw accepted time of flight values minus the trend function.
F7.3	Bin kurtosis from the mean of raw accepted time of flight values minus the trend function.
F9.1	Bin peak – mean value (ps)
F5.1	Return rate (%) for SLR or signal to noise ratio for LLR.
I1	Detector channel 0 = not applicable or “all” 1-4 for quadrant 1-n for many channels

3.2.2. Notes

Note that station transmit and receive times are nominally with respect to the system reference point (SRP) which will in many cases be the telescope invariant point. This requires a knowledge of both the transmit delay and receive delay, which is critical for transponder ranging. It is less critical for normal satellite (two-way) ranging since errors in distributing the system delay to these components will cancel.

If there are too few data points to assess pass rms, skew, or kurtosis, put “-1” in the field. It is left to the station’s discretion, subject to ILRS directives, whether to include normal points having few data points. Kurtosis calculations should follow the convention in which 3 is subtracted, so that the kurtosis for a normal distribution is 0.

Detector channel will normally be '0' even for multi-channel systems. This field is included for flexibility.

As an example of CRD flexibility, LRO normal points will use F28.12 rather than F18.12 for spacecraft receive time format.

3.3.Range Supplement Record

The range supplement range record contains optional range data and will be interspersed with range data to which it is associated. If this record is used, then it should be created whenever there is a *significant* change to one or more fields.

3.3.1.Format:

A2(1-2) Record Type (= "12")
F18.12 Seconds of day.
A4 System configuration id.
F6.1 Tropospheric refraction correction (picoseconds, 1 way)
F6.4 Target center of mass correction (meters, 1 way)
F5.2 Neutral density (ND) filter value
F8.4 Time bias applied (seconds)

3.3.2.Notes

None.

3.4.Meteorological Record

This data record contains a minimal set of meteorological data. At least one record must appear in the data file.

3.4.1.Format:

A2(1-2) Record Type (= "20")
F18.12 Seconds of day (typically to 1 millisec)
F7.2 Surface pressure (mbar).
F6.2 Surface temperature in degrees Kelvin.
F4.0 Relative humidity at Surface in %
I1 Origin of values
0 = measured values (written whenever a value changes “significantly”)
1 = interpolated values applicable at time (seconds of day) given in this record

3.4.2.Notes

Sample meteorological records should only be written when one of the fields changes “significantly”. As a minimum, a new record should be written whenever pressure changes by 0.1mB, the temperature changes by 0.1 K, or when the humidity changes by 5%. The time (seconds of day) of an interpolated record should match the time in the following normal point record.

In cases where only sample values are provided in a normal point file, the station is indicating that the

values are slowly varying and that the analysts may apply the values in the last meteorological record preceding a normal point record to that normal point. Analysts may always interpolate these values, but this should not be necessary.

3.5.Meteorological Supplement Record

This data record contains an (optional) supplement set of meteorological data. A file must contain at least one meteorological record and may contain one or more meteorological supplement records.

3.5.1.Format:

A2(1-2) Record Type (= "21")
F18.12 Seconds of day (typically to 1 millisec)
F5.1 Wind speed (m/s)
F5.1 Wind direction (degrees azimuth, north is zero)
A4 Precipitation type ("rain", "snow", "fog", "fine" ...TBD)
I3 Visibility (km)
F4.2 Sky clarity (ie zenith extinction coefficient)
I2 Atmospheric seeing (arcsec)
I2 Cloud cover (%)

3.5.2.Notes

Meteorological records should only be written when one of the fields changes "significantly". The criteria should be at least 2 times the least significant bit of the sensor, to prevent noise in the lowest bit from constantly producing new records.

3.6.Pointing Angles Record

This record contains telescope or beam director pointing (azimuth and elevation) angles, and is optional for normal point data sets. If it is used, the source and nature of this data must be provided.

3.6.1.Format:

A2(1-2) Record Type (= "30")
F18.12 Seconds of day (typically to 1 millisec)
F8.4 Azimuth in degrees
F8.4 Elevation in degrees
I1 Direction flag
 0 = transmit & receive
 1 = transmit
 2 = receive
I1 Angle origin indicator

- 0 = unknown
- 1 = computed
- 2 = commanded (from predictions)
- 3 = measured (from encoders)

I1 Refraction corrected

- 0 = False (in vacuo angles ie angles if no atmosphere is assumed)
- 1 = True (apparent angles with refraction included)

3.6.2. Notes

Point angle records should only be written when one of the angles changes “significantly”. The meaning of “significantly” should be defined by the producers and users of this data.

The pointing angles seem to be seldom used in practice. In most cases when pointing angles are used in data analysis, it is as a cross check that the pass and station location have been correctly identified. There may be cases where pointing angles are used with or without ranging data as a fundamental data type in precision orbit determination. In these cases, the frequency and care taken in compiling these angle measurements will be much greater. In this case, it is also possible that pointing angles records will be needed with normal points.

3.7. Calibration Record

The calibration record contains statistics of accepted calibration measurements. It may be associated with calibrations at the station or target. The file will contain as many calibration records as required, but there must be at least one station calibration record in the file at the station level. Each calibration record is applicable to the subsequent block(s) of range records. There can also be calibrations records to represent several “Types of data”. For a transponder for which all fires must be recorded as well as returns, there should be type 0 (normal ranging) and 1 (station transmit)

3.7.1. Format:

A2(1-2) Record Type (= "40")

F18.12 Seconds of day (typically to < 100ns for SLR/LLR or <1 ps for transponder ranging). Station clock corrections should be applied for all targets.

I1 Type of data

- 0=station combined transmit and receive calibration (“normal” slr/llr)
- 1=station transmit calibration (e.g., one-way ranging to transponders)
- 2=station receive calibration
- 3=target combined transmit and receive calibrations
- 4=target transmit calibration
- 5=target receive calibration

A4	System configuration id
I8	Number of data points recorded (= -1 if no information)
I8	Number of data points used (= -1 if no information)
F7.3	One way target distance (meters, nominal) (= -1 if no information)
F10.1	Calibration System Delay (picoseconds)
F8.1	Calibration Delay Shift - a measure of calibration stability (picoseconds).
F6.1	Root Mean Square (RMS) of raw system delay (ps). If pre- and post- pass calibrations are made, use the mean of the two RMS values, or the RMS of the combined data set.
F7.3	Skew of raw system delay values from the mean. If pre- and post- pass calibrations are made, use the mean of the two skew values, or the skew of the combined data set.
F7.3	Kurtosis of raw system delay values from the mean. If pre- and post- pass calibrations are made, use the mean of the two kurtosis values, or the kurtosis of the combined data set.
F6.1	System delay peak – mean value (ps)
I1	Calibration Type Indicator <ul style="list-style-type: none"> 0 = Not used or undefined 1 = Nominal (from once off assessment) 2 = External cals 3 = Internal cals 4 = Burst cals 5 = Other
I1	Calibration Shift Type Indicator <ul style="list-style-type: none"> 0 = Not used or undefined 1 = Nominal (from once off assessment) 2 = Pre – to Post- Shift 3 = Minimum to maximum 4 = Other
I1	Detector channel <ul style="list-style-type: none"> 0 = not applicable or “all” 1-4 for quadrant 1-n for many channels

3.7.2. Notes

“Nominal” calibrations are intended for generally low accuracy systems that do not have access to high precision system delay measurements, but rather depend on fairly static and infrequent assessments of system delay. For example, use “nominal” calibrations for engineering data while a station is being developed, or for other special purposes.

Kurtosis calculations should follow the convention in which 3 is subtracted, so that the kurtosis for a normal distribution is 0.

It is expected that one calibration record is included for a normal point data block, but this record could be used to also provide single shot measurements or averaged blocks (“normal points”) of internal calibrations for example.

3.8.Session (Pass) Statistics Record

The session (pass) statistics record contains averaged statistics derived from measurements taken during the session (or over the duration of a pass). The file will contain blocks of one or more range records corresponding to a consistent format. One session statistics record should be associated with each of these data blocks.

3.8.1.Format:

- A2(1-2) Record Type (= "50")
- A4 System configuration id.
- F6.1 Session RMS from the mean of raw, accepted time of flight values minus the trend function (ps).
- F7.3 Session Skewness from the mean of raw accepted time of flight values minus the trend function.
- F7.3 Session Kurtosis from the mean of raw accepted time of flight values minus the trend function.
- F6.1 Session peak – mean value (ps)
- I1 Data quality assessment indicator. For SLR and LLR data:
 - 0 = Undefined or no comment.
 - 1 = Clear, easily filtered data, with little or no noise.
 - 2 = Clear data with some noise; filtering is slightly compromised by noise level.
 - 3 = Clear data with a significant amount of noise, or weak data with little noise. Data are certainly present, but filtering is difficult.
 - 4 = Un-clear data; data appear marginally to be present, but are very difficult to separate from noise during filtering. Signal to noise ratio can be less than 1:1.
 - 5 = No data apparent.

3.8.2.Notes

This record is only required in combination with a number of normal point records. It is optional with full rate or engineering data records.

Kurtosis calculations should follow the convention in which 3 is subtracted, so that the kurtosis for a normal distribution is 0.

3.9.Compatibility Record

This record is provided primarily to allow reformatting of old data from the ILRS normal point and full-rate data to this format, without losing existing data.

3.9.1.Format:

A2(1-2) Record Type (= "60").

A4 System configuration id.

I1 System CHange indicator (SCH)

A flag to increment for every major change to the system (hardware or software). After the value '9' return to '0', and then continue incrementing. The station and data centers should keep a log in a standard format of the value used, the date of the change, and a description of the change.

I1 System Configuration Indicator (SCI)

A flag used to indicate alternative modes of operation for a system (e.g., choice of alternative timers or detectors, or use of a different mode of operation for high satellites). Each value of the flag indicates a particular configuration, which is described in a log file held at the station and at the data centers. If only a single configuration is used then use a fixed value. If a new configuration is introduced then use the next higher flag value. If value exceeds '9' then return to '0', overwriting a previous configuration flag (it is not likely that a station will have 10 current possible configurations).

3.9.2.Notes

None.

3.10.User Defined Record

This record is provided to allow special interest users or groups to add non-standard data records. Other users must be able to ignore such records (if they exist in a file) without any impact. Record types outside this range will be reserved for future standard format use.

3.10.1.Format:

A2(1-2) Record Type (= "9X", X = 0...9).

3-80 User defined format

3.10.2.Notes

These records should normally be stripped from the file before being sent to the operations center.

3.11.Comment Record

Comment records are optional, and allow users to insert comments or notes as deemed necessary and appropriate. This especially pertains to any data quality issues designated in the header H4.

3.11.1.Format:

A2(1-2) Record Type (= "00").

A80 Free format ASCII comments (terminated by an end-of-line character).

3.11.2.Notes

To ensure line lengths do not become excessive, a limit of 80 characters is set. Lines exceeding this limit may be truncated. Multiple comment lines are encouraged. Comment lines can occur anywhere within a file.

4. Record Structure

The records as defined should have the potential for storing a quite complex mix of data types while maintaining data integrity. The format must support a consistent, unambiguous data set that can be readily parsed for currently used and expected data sets, and for data sets that are possible in the future. The data stored in a CRD file should be capable of being stored in a normalized database and/or expressed in the XML language. The definitions of the records have kept this in mind.

It is important that, unless totally unavoidable, data fields are not repeated as this has the potential for undermining the requirement for unambiguous and consistent data. It is also efficient in terms of file sizing and storage.

The following table shows the permissible combination of records by data type. Normally, files will contain only one data type - full rate, sampled engineering, or normal point. However, the format does allow combining these files as separate blocks within a data file. See example 6.5. Another way to do this for a single pass is to start with a common h1/h2/h3 record set. The first h4 through h8 block could contain full rate data, for instance. The second h4 through h8 block could contain sampled engineering, and the third such block could contain the normal points. This is possible because the h4 record contains the date type for the data following (through h8).

Record	Full Rate	Sampled Engineering (Rarely used)	Normal Point
Header Section			
H1 - Format	√	√	√
H2 - Station	√	√	√
H3 - Target	√	√	√
H4 -Session (Pass)	√	√	√
H8 - EOS	√	√	√
H9 - EOF	√	√	√
Configuration Section			
C0 – System Configuration	√	√	√
C1 – Laser Configuration	recommended	recommended	recommended
C2 – Detector Configuration	recommended	recommended	recommended
C3 – Timing Configuration	recommended	recommended	recommended
C4 - Transponder Config	√ transponders; n/a for other targets	√ transponders; n/a for other targets	√ transponders; n/a for other targets
Data Section			
10 - Range	√	√	not allowed
11 – Normal point	not allowed	not allowed	√

12 – Range Supplement	as available	as available	as available
20 - Meteorological	√	√	√
21 – Meteorological Supp	as available	as available	as available
30 – Pointing angles	√	√	n/r (usually)
40 – Calibration Statistics	n/r	n/r	√
50 – Session Statistics	n/r	n/r	√
60 - Compatibility	√ if no C1-C3; n/r otherwise	√ if no C1-C3; n/r otherwise	√ if no C1-C3; n/r otherwise
9x – User defined	Usually not transmitted	Usually not transmitted	Usually not transmitted
00 - Comments	as needed	as needed	as needed

n/a = not applicable or not appropriate

n/r = not required

√ = required

Consider a number of cases. The first is simple case where the station is performing basic satellite tracking and is creating full rate and normal point files. In practice, this will probably represent the majority of files most of the time, at least for the present.

A more complex case where a station is performing two-color ranging and wants to store both full rate and normal point data in the one file, or when a site is publishing full rate data from experiments in time transfer using target transponders.

4.1.Case 1

Two files containing full rate for one target and normal point data for one period (for example, one day). This is typical for existing normal point (.qld) and fullrate (.fr) files being generated at many stations. (Comment records are not considered here.) As can be seen from the sample data in section 6, there can be some legitimate variations in record sequence.

Full rate file for 1 target, single system configuration.

Format Header

Station Header

Target Header

Laser Configuration Record

Detector Configuration Record

Timing System Configuration Record

System Configuration Record

Calibration Record

Session Header

Calibration Record (if required)

Pointing Record / Mets Record

Data Record (Full rate) (repeated)

Calibration Record / Pointing Record / Mets Record (as required)

Data Record (Full rate) (repeated)

Calibration Record (if required)

Pointing Record / Mets Record

End Of Session Header

Session Header

Calibration Record (if required)

Pointing Record / Mets Record

Data Record (Full rate) (repeated)

Calibration Record / Pointing Record / Mets Record (as required)

Data Record (Full rate) (repeated)

Calibration Record (if required)

Pointing Record / Mets Record

End of session Header

..... (as many session as required)

End of file header

Normal point file for many targets, single system configuration.

Format Header

Station Header

Laser Configuration Record

Detector Configuration Record

Timing System Configuration Record

System Configuration Record

Calibration Record

Target Header

Session Header

Calibration Record (if required)

Mets Record

Data record (normal point) (repeated)
 Mets Record
 Data record (normal point) (repeated)
 Mets Record
 Pass Record
 End of session header
 other sessions for this target as required
 Target Header
 Repeat as above for as many targets as required
 End of session header
 End of file header

This would correspond to files having a record sequence such as

H1 H2 C0 C1 C2 C3 40 H3 H4 20 30 40 10 10 10...20 10 10...30 10 10...40...10 10 20 H8 H4 20 30 40
 10 10 10...20 10 10...30 10 10...40...10 10 20 H8 H4...H8...H9

and

H1 H2 C0 C1 C2 C3 40 H3 H4 40 20 11 11 11...20 11 11...20.12 H8 H4 40 20 11 11 11...20 12 H8 H3
 H4 40 20 11 11 11...20 11 11...20 12 H8 H4 40 20 11 11 11...20 12 H8...H8...H9

4.2.Case 2

One file containing full rate and normal point data for one target for one period (for example, one day) from a station performing two-color ranging (or any other dual configuration) ranging.

Full rate and normal point file for 1 target, two system configurations.

Format Header
 Station Header
 Target Header
 Laser Configuration L1 Record
 Laser Configuration L2 Record
 Detector Configuration D1 Record
 Detector Configuration D2 Record
 Timing System Configuration (TS) Record

System Configuration S1 Record (L1-D1-TS)

System Configuration S2 Record (L2-D2-TS), or whatever is appropriate

Calibration (system S1) Record C1

Calibration (system S2) Record C2, or whatever is appropriate.

Session Header (full rate)

Calibration Records C1 and/pr C2 (if required)

Pointing Record / Mets Record

Data Record for S1 (Full rate) (repeated)

Data Record for S2 (Full rate) (repeated)

Calibration Records / Pointing Record / Mets Record (as required)

Data Records for S1 (Full rate) (repeated)

Data Records for S2 (Full rate) (repeated)

Calibration Records (if required)

Pointing Record / Mets Record

End of session Header

Session Header (normal point)

Mets Record

Data Record for S1 and/or S2(normal point) (repeated)

Mets Record

Data Record for S1 and/or S2 (normal point) (repeated)

Mets Record

End of session Header

Session Header (full rate)

.... (Repeat as above for as many sessions as required)

End of session Header

End of file header

This would correspond to files having a record sequence such as

H1 H2 H3 C0 C0 C1 C1 C2 C2 C3 H4 20 30 40 40 10 10 10 10...20 10 10 10 10...30 10 10 10
10...40...10 10 20 H8 H4 20 11 11 11 11...20 11 11 11 11...11 11 11 11...11 11 20 H8 H4 20 30 40 40
10 10 10 10...20 10 10 10 10...30 10 10 10 10...40...10 10 20 H8 H4 20 11 11 11 11...20 11 11 11
11...11 11 11 11...11 11 20 H8...H8 H9.

4.3.Case 3

One file containing full rate data for one target from a station performing experiments in time transfer via a transponder in association with another station.

Full rate 1 target, two system configurations.

Format Header

Station Header

Target Header

Laser Configuration Record

Detector Configuration Record

Timing System Configuration Record

Transponder Configuration Record

System Configuration Record

Calibration Record (Site)

Calibration Record (Target)

 Session Header (full rate)

 Calibration Record (Site) (if required)

 Calibration Record (Target) (if required)

 Pointing Record / Mets Record

 Data Record (Full rate, time of flight and transmit epoch) (repeated)

 Data Record (Full rate, receive epoch only) (repeated)

 Pointing Record / Mets Record

 End of session Header

End of file header

4.4.Case 4

In this case, several fullrate or normal point sessions from one station are sent in a single file from the station to a data center. There are two ways of doing this:

4.4.1.Preferred method

H1 H2 H3 H4 ... H8

 H3 H4 ... H8

 ...

 H3 H4 ... H8 H9

This ordering is more hierarchical and is more compatible with parsing into XML.

4.4.2.Acceptable, but not preferred, method

H1 H2 H3 H4 ... H8

H1 H2 H3 H4 ... H8

...

H1 H2 H3 H4 ... H8 H9

This ordering is syntactically correct, and may be easier to implement when converting data in the old format to CRD.

5. File Naming

Since the proposed data format is so flexible and a file could contain many data types and cover any period of time, file naming becomes a real issue. Therefore the following conventions that have been adopted.

1. File names and file naming conventions do not form the basis for file processing except for files that have well defined and specific file extensions (such as .Z for extraction purposes). File processing will require files to be opened and parsed to determine what operations, if any, are to be performed.
2. File names ending in “.npt”, “.frd”, or “.qlk” contain single data types, but possibly multiple satellites and stations.
3. File names ending in “.crd” may contain multiple data types.
4. File names ending in “.frf” contain all the laser fire times and do not contain valid times of flight or receive times. This is for one-way transponder missions such as LRO.
5. Files are delivered to specific file repositories in which it has been agreed and understood that certain file operations will be performed. Hence the onus is on the supplier to provide the appropriate type of file to the repository.
6. Published files will always have a unique file name. (Pertains to station naming conventions.)
7. Release versions are maintained within the data file headers for every pass or session. Station file names will echo this release number (if it is consistent within the file), but data center file names will not - those files will always contain the latest data release.

5.1. Station Naming Convention

This naming convention is for use with files transmitted from the station to the operations centers (unless there is a prior agreement for another protocol).

5.1.1 Single Pass and Data Type

5.1.1.1 Ftp or Scp

File names for ftp or scp transfer should be

ssss_satname_crd_yyyymmdd_hh_rr.typ

where

ssss is the CDP Pad Identifier (station number)

satname is from a standard ILRS list of spacecraft (lower case)

yyymmdd is the start date of pass (UTC)

hh is the start time of pass (hour only, UTC time scale)

rr is the release number (initial release = "00")

typ is the data type:

frd – full-rate data,

qlk – sampled engineering ("quicklook") data,

npt – normal point data,

crd – mixed or unspecified file contents, or

frf – full-rate data with fire times only.

Geostationary satellite "passes" could be submitted in several files, depending on the tracking schedules. Files may contain the ".Z", ".z", or ".zip" extension indicating a particular type of file compression.

5.1.1.2 E-mail Transmission

For e-mail submission this filename should be part of the Subject field

Subject: npt data ssss_satellite_crd_yyyymmdd_hh_rr

5.1.2 Several Passes or Data Types

To submit several normal point, sampled engineering, fullrate files or a combination of files at once, there are 2 recommended procedures. Note that these procedures can be used for ftp/scp transfers, not email.

5.1.2.1 Combined File

Send a single combined ASCII file. The description of a combined file name is:

ssss_[satname_]crd_yyyy[mm[dd[_hh]]]_rr.typ

where the fields are the same as above, and the brackets "[]" enclose fields that can be omitted depending on the file contents. Note that the station is always included, since the file comes from a single station. A split program (available in the sample code) will be required at the operations center break this file into its component files.

Examples:

7080_crd_20071012_14_00.npt	- normal points for several passes from different satellites, starting at a particular hour
7080_lageos1_crd_200206_99.crd	- lageos-1 data for a month, with mixed releases
7080_crd_2003_99.frd	- fullrate data for a year, with mixed releases.

Notes:

- 1) This can cover mass resubmissions of data with a single (new) revision level.
- 2) Where there are more than one revision level in a file, the release number should be "99".
- 3) In the case where several data types are mixed in a file, the typ could be "crd".

5.1.2.2 Tar or Zipped File

'Zip' or 'tar' together several files into a larger file having an appropriate name:

ssss_crd_yyyy[mm[dd[_hh[mm]]]]_rr.com,

where

satname has been omitted,

mm is minute, which has been added to permit more than one transmission an hour, and
com is the compression program extension:

zip, or
tgz.

Examples:

7080_crd_2005_01.zip - an update to some 2005 data files
7090_crd_20071012_1500_00.tgz - a typical hourly transfer

5.2.Data Center Naming Convention

Data centers (e.g. CDDIS and EDC) will use these file names at their ftp and web sites. These are the file names the users will see when retrieving data for their analysis work. Each file will contain only one type of data.

satname_yyyymmddhh.typ (hourly)
satname_yyyymmdd.typ (daily)
satname_yyyymm.typ (monthly)
satname_yyyy.typ

where

- satname is from a standard ILRS list of spacecrafts;
- yyyy is the 4-digit year,
- mm is the 2-digit month,
- dd is the 2-digit day,
- hh is the 2-digit hour, and
- typ is
 - frd – full-rate data,
 - qlk – engineering sampled engineering data,
 - npt – normal point data.

Examples: starlette_2006091011.frd
 lro_200810.npt

Files may contain the “.Z” or “.z” extension indicating file compression.

6. Sample Files

This section includes passes and samples of passes represented in the CRD format. Note that record lengths were kept short by using “%.xf” c language formats for most floating point fields.

6.1.Fullrate

Filename: 7080_lageos2_crd_20061113_15_00.frd

```
H1 CRD 1 2007 3 20 14
H2 MLRS 7080 24 19 4
H3 LAGEOS2 9207002 5986 22195 0 1
H4 0 2006 11 13 15 23 52 2006 11 13 15 45 35 1 1 1 1 0 0 2 0
C0 0 532.000 std1
60 std1 5 2
10 55432.0414338 0.047960587856 std1 2 0 0 0 0
12 55432.0414338 std1 20735.0 1601.0000 0.00 0.0000
20 55432.0414338 801.80 28.21 39 0
30 55432.0414338 297.2990 38.6340 0 2 1
40 55432.0414338 0 std1 -1 -1 0.000 -913.0 0.0 56.0 -1.000 -1.000 -1.0 3 3 0
10 55435.6429746 0.047926839980 std1 2 0 0 0 0
12 55435.6429746 std1 20697.0 1601.0000 0.00 0.0000
30 55435.6429746 297.4480 38.7190 0 2 1
...
10 56735.8021609 0.046094881873 std1 2 0 0 0 0
12 56735.8021609 std1 18092.0 1601.0000 0.00 0.0000
30 56735.8021609 15.2330 45.7100 0 2 1
H8
H9
```

6.2.Normal Point

File name: 7080_lageos2_crd_20061113_15_00.npt

```
H1 CRD 1 2007 3 20 14
H2 MLRS 7080 24 19 4
H3 LAGEOS2 9207002 5986 22195 0 1
H4 1 2006 11 13 15 25 4 2006 11 13 15 44 40 0 0 0 0 1 0 2 0
C0 0 532.000 std1
60 std1 5 2
11 55504.9728030 0.047379676080 std1 2 120 18 94.0 -1.000 -1.000 -1.0 0.0 0
20 55504.9728030 801.80 282.10 39 1
40 55504.9728030 0 std1 -1 -1 0.000 -913.0 0.0 56.0 -1.000 -1.000 -1.0 3 3 0
11 55988.9809589 0.044893190432 std1 2 120 19 83.0 -1.000 -1.000 -1.0 0.0 0
20 55988.9809589 801.50 282.80 39 1
11 56141.8467215 0.044635017248 std1 2 120 28 66.0 -1.000 -1.000 -1.0 0.0 0
11 56223.2817254 0.044605221903 std1 2 120 25 87.0 -1.000 -1.000 -1.0 0.0 0
20 56223.2817254 801.50 282.60 39 1
11 56373.5463612 0.044746486398 std1 2 120 25 78.0 -1.000 -1.000 -1.0 0.0 0
20 56373.5463612 801.50 282.10 39 1
11 56439.9749454 0.044889147842 std1 2 120 25 99.0 -1.000 -1.000 -1.0 0.0 0
11 56565.2288146 0.045288773098 std1 2 120 25 92.0 -1.000 -1.000 -1.0 0.0 0
11 56680.8785419 0.045804632570 std1 2 120 10 55.0 -1.000 -1.000 -1.0 0.0 0
20 56680.8785419 801.50 282.00 39 1
50 std1 86.0 -1.000 -1.000 -1.0 0
H8
H9
```

6.3. Sample Engineering (Quicklook)

File name: 7080_lageos2_crd_20061113_15_00.qlk

```
H1 CRD 1 2007 3 20 14
H2 MLRS 7080 24 19 4
H3 LAGEOS2 9207002 5986 22195 0 1
H4 2 2006 11 13 15 24 17 2006 11 13 15 44 59 0 0 0 0 0 0 2 0
C0 0 532.000 std1
60 std1 5 2
10 55457.0521861 0.047753624332 std1 2 0 0 0 0
20 55457.0521861 801.80 282.10 39 0
30 55457.0521861 298.3470 39.2230 0 0 0
10 55482.4631214 0.047552685849 std1 2 0 0 0 0
30 55482.4631214 299.4370 39.8100 0 0 0
...
10 56589.0390552 0.045383653062 std1 2 0 0 0 0
20 56589.0390552 801.50 282.00 39 0
30 56589.0390552 6.7380 47.9120 0 0 0
10 56623.4538362 0.045531247776 std1 2 0 0 0 0
30 56623.4538362 8.8120 47.4510 0 0 0
10 56657.6685552 0.045690091816 std1 2 0 0 0 0
30 56657.6685552 10.8230 46.9570 0 0 0
10 56699.7866762 0.045901952309 std1 2 0 0 0 0
30 56699.7866762 13.2310 46.3060 0 0 0
50 std1 86.0 -1.000 -1.000 -1.0 0
H8
H9
```

6.4. Sample 2-Color Normal Point file

File Name: 7810_lageos1_crd_20061230_07_00.npt

```
H1 CRD 1 2007 3 20 14
H2 ZIMMERWALD 7810 68 1 7
H3 LAGEOS1 7603901 1155 8820 0 1
H4 1 2006 12 30 7 35 34 2006 12 30 8 12 29 0 0 0 0 1 0 2 0
C0 0 846.000 std1
C0 0 423.000 std2
60 std1 9 0
60 std2 9 1
11 27334.1080890 0.051571851861 std1 2 120 36 154.0 -1.000 -1.000 -1.0 0.0 0
20 27334.1080890 923.30 275.40 43 1
40 27334.1080890 0 std1 -1 -1 0.000 113069.0 0.0 138.0 -1.000 -1.000 -1.0 2 2 0
11 27343.5080895 0.051405458691 std2 2 120 28 79.0 -1.000 -1.000 -1.0 0.0 0
11 27372.6080888 0.050895050517 std2 2 120 30 76.0 -1.000 -1.000 -1.0 0.0 0
11 27373.1080893 0.050886342010 std1 2 120 17 158.0 -1.000 -1.000 -1.0 0.0 0
11 28003.8080894 0.042252027043 std1 2 120 19 170.0 -1.000 -1.000 -1.0 0.0 0
20 28003.8080894 923.40 275.50 42 1
11 28008.7080899 0.042208378233 std2 2 120 85 71.0 -1.000 -1.000 -1.0 0.0 0
11 28402.1080897 0.040251470202 std1 2 120 6 183.0 -1.000 -1.000 -1.0 0.0 0
11 28406.5080897 0.040247878310 std2 2 120 45 78.0 -1.000 -1.000 -1.0 0.0 0
11 28620.0080896 0.040574433849 std1 2 120 18 163.0 -1.000 -1.000 -1.0 0.0 0
20 28620.0080896 923.50 275.50 42 1
11 28627.6080899 0.040603966534 std2 2 120 114 71.0 -1.000 -1.000 -1.0 0.0 0
11 29151.2080895 0.045287136931 std2 2 120 7 65.0 -1.000 -1.000 -1.0 0.0 0
11 29156.7080892 0.045360524908 std1 2 120 7 134.0 -1.000 -1.000 -1.0 0.0 0
20 29156.7080892 923.50 275.80 42 1
11 29225.6080889 0.046314735294 std1 2 120 45 164.0 -1.000 -1.000 -1.0 0.0 0
11 29237.7080892 0.046488750878 std2 2 120 50 78.0 -1.000 -1.000 -1.0 0.0 0
```

```

11 29326.8080894 0.047825380133 std1 2 120 49 152.0 -1.000 -1.000 -1.0 0.0 0
11 29334.2080895 0.047940570614 std2 2 120 73 85.0 -1.000 -1.000 -1.0 0.0 0
11 29461.4080892 0.050011219353 std2 2 120 29 76.0 -1.000 -1.000 -1.0 0.0 0
11 29477.2080896 0.050279566397 std1 2 120 25 187.0 -1.000 -1.000 -1.0 0.0 0
11 29544.4080897 0.051445695153 std1 2 120 19 164.0 -1.000 -1.000 -1.0 0.0 0
11 29549.5080897 0.051535764981 std2 2 120 14 87.0 -1.000 -1.000 -1.0 0.0 0
50 std1 165.0 -1.000 -1.000 -1.0 0
50 std2 78.0 -1.000 -1.000 -1.0 0
H8
H9

```

6.5. Sample showing all current record types

```

00 This is a recent MLRS normal point file.
00 Plausible '21' records have been added
00 Part of the full rate file has been added, so keep reading.
h1 CRD 1 2008 3 25 1
h2 MDOL 7080 24 19 4
h3 jason1 105501 4378 26997 0 1
h4 1 2008 3 25 0 45 17 2008 3 25 0 55 9 0 0 0 0 1 0 2 0
c0 0 532.000 std m11 mcp mt1
c1 0 m11 Nd-Yag 1064.00 10.00 100.00 200.0 -1.00 1
c2 0 mcp mcp 532.000 -1.00 3800.0 0.0 unknown -1.0 0.00 -1.0 0.0 none
c3 0 mt1 TAC TAC MLRS_CMOS_TMRB_TD811 na 445.9
60 std 5 2
40 2716.0000000 0 std 67 58 -1.000 -883.3 0.0 96.4 0.718 -0.126 364.4 3 3 0
20 2716.000 801.73 286.76 35. 0
21 2716.000 3.1 45 none 20 -1 3 10
11 2726.697640514675 0.013737698432 std 2 15 1 72.7 1.494 -0.536 -32.4 0.67 0
11 2804.507921286791 0.011496837034 std 2 15 1 72.7 1.494 -0.536 -32.4 0.67 0
11 2810.908760187949 0.011334723870 std 2 15 16 65.4 1.229 -1.235 -33.5 10.67 0
20 2822.000 801.73 286.56 35. 0
11 2828.611102554046 0.010908518342 std 2 15 1 72.7 1.494 -0.536 -32.4 0.67 0
11 2850.814029348448 0.010424908601 std 2 15 3 116.6 0.649 -2.333 -86.7 2.00 0
11 3104.347543373788 0.010760099652 std 2 15 2 108.7 0.354 -2.750 -73.5 1.33 0
11 3113.248715491056 0.010963708963 std 2 15 11 78.5 1.345 -0.730 -45.8 7.33 0
11 3124.950255557618 0.011244819341 std 2 15 14 65.2 1.635 0.207 4.5 9.33 0
11 3142.652594816107 0.011696747487 std 2 15 12 74.2 1.369 -0.535 -161.6 8.00 0
11 3150.653650787761 0.011910674436 std 2 15 2 123.0 0.354 -2.750 -83.7 1.33 0
20 3151.000 801.73 286.16 35. 0
21 3152.000 2 80 fog 20 -1 3 10
11 3169.356124039857 0.012431881802 std 2 15 1 72.7 1.494 -0.536 -32.4 0.67 0
50 std 72.7 1.494 -0.536 -32.4 0
h8
00 Note that there was no h9 "end of file" record after the "h8",
00 so this is a different part of the same file.
00
00 The following is part of the full-rate file from the same pass.
00 '21' records have been added to this example.
00 Even though this is not transponder data, a c4 record has been dummied.
00 The 'mcl' clock field id for the c4 record was added to the c0 record.
00 The file also contains 91, 92, and 93 records, which are user-defined.
00 Station-defined records will normally be stripped off by the station before transmittal.
00 Just bypass them as you do not know the format.
00 The analysts can also add their own 9x records if they wish.
h1 CRD 1 2008 3 25 1
h2 MDOL 7080 24 19 4
h3 jason1 105501 4378 26997 0 1
h4 0 2008 3 25 0 45 17 2008 3 25 0 55 9 0 0 0 0 1 0 2 0
c0 0 532.000 std m11 mcp mt1 mcl
c1 0 m11 Nd-Yag 1064.00 10.00 100.00 200.0 -1.00 1
c2 0 mcp mcp_varamp 532.000 -1.00 3800.0 0.0 unknown -1.0 0.00 -1.0 0.0 none
c3 0 mt1 TAC TAC MLRS_CMOS_TMRB_TD811 na 445.9
c4 0 mcl 0.000 0.00 1234567890123456.789 0.00 0.000000000000 0 0 0
60 std 5 2
91 8 85 2640 -2438728.97 -4909741.31 5429800.07 1474.0965 -5367.5721 -4187.1144 2
20 2716.000 801.73 286.76 35 0
21 2716.000 3.1 45 none 20 -1 3 10
40 2716.0000000 0 std 67 58 -1.000 -883.3 0.0 96.4 0.718 -0.126 364.4 3 3 0
30 2717.996 326.8923 32.9177 0 1 1
12 2717.9964890 std 0.0 0.0000 0.00 0.0000
30 2725.897 326.6035 33.9991 0 1 1

```

```

10 2726.697640514675 0.013737698432 std 2 2 0 0 0
30 2734.998 326.2469 35.2830 0 1 1
10 2738.899248614531 0.013359440021 std 2 1 0 0 0
30 2742.799 325.9195 36.4168 0 1 1
30 2752.100 325.4955 37.8239 0 1 1
10 2752.100991800282 0.012962363200 std 2 1 0 0 0
30 2762.002 324.9939 39.3585 0 1 1
...
21 3309.000 2 80 fog 20 -1 3 10
30 3309.224 164.3231 22.4342 0 1 1
10 3309.224609210523 0.016974823000 std 2 1 0 0 0
93 3309.224609210523 std 0.000 16.660 -20.265 0.97511 -0.00099 -2416.305 35267.021
92 3309.000 -0.0003 0.0003
h8
h9

```

6.6. Sample demonstrating free format

The following data was written by 2 different programs, showing how field spacing and length can differ in the configuration and data sections.

File 1:

```

h1 CRD 1 2008 5 8 19
h2 MDOL 7080 24 19 4
h3 giovea 505101 7001 28922 0 1
h4 1 2008 5 8 9 40 23 2008 5 8 9 50 45 0 0 0 0 1 0 2 0
c0 0 532.000 std m11 mcp_with_amp mt1
c1 0 m11 Nd-Yag 1064.00 10.00 100.00 200.0 -1.00 1
c2 0 mcp_with_amp mcp_and_avantek_amp 532.000 -1.00 3800.0 0.0 unknown -1.0 0.00 -1.0 0.0 none
c3 0 mt1 TAC TAC MLRS_CMOS_TMRB_TD811 na 439.45
60 std 5 2
40 34823.000 0 std 398 190 -1.000 402.3 0.0 131.1 0.168 -0.130 494.4 3 3 0
20 34823.000 796.55 287.86 24. 0
11 34945.620986680762 0.167738944021 std 2 300 116 193.32 1.821 0.904 -22.8 3.87 0
11 35237.103254500325 0.167288847260 std 2 300 143 173.04 1.601 -0.009 -61.3 4.77 0
11 35422.490473700898 0.167002428581 std 2 300 19 179.75 1.318 -0.974 -259.7 0.63 0
50 std 178.8 1.711 0.451 -128.2 0
h8
h9

```

File 2:

```

h1 CRD 1 2008 5 8 19
h2 MDOL 7080 24 19 4
h3 giovea 505101 7001 28922 0 1
h4 1 2008 5 8 9 40 23 2008 5 8 9 50 45 0 0 0 0 1 0 2 0
c0 0 532.000 std m11 mcp mt1
c1 0 m11 Nd-Yag 1064.00 10.00 100.00 200.0 -1.00 1
c2 0 mcp mcp 532.000 -1.0 3800.0 0.0 unknown -1.0 0.00 -1.0 0.00 none
c3 0 mt1 TAC TAC MLRS_CMOS_TMRB_TD811 na 439.4
60 std 5 2
40 34823.000000 0 std 398 190 -1.000 402.3 0.0 131.1 0.168 -0.130 494.4 3 3 0
20 34823.000 796.55 287.86 24. 0
11 34945.620986680762 0.167738944021 std 2 300 116 193.3 1.821 0.904 -22.8 3.87 0
11 35237.103254500325 0.167288847260 std 2 300 143 173.0 1.601 -0.009 -61.3 4.77 0
11 35422.490473700898 0.167002428581 std 2 300 19 179.7 1.318 -0.974 -259.7 0.63 0
50 std 178.8 1.711 0.451 -128.2 0
h8
h9

```

6.7. Sample Transponder Configuration Segment

The previous examples were converted from existing data files. For new data where configuration

information is available while forming the CDR, the following could replace or supplement the C0 and 60 records for MLRS tracking a lunar transponder. (The values are not necessarily realistic.)

One way (detector not used):

```
C0 0 532.0 std1 las1 tim1 lro
C1 0 las1 Nd-Yag 1064.0 10.0 100 200 20 1
C3 0 tim1 TAC na MLRS na 0
C4 0 lro 100 5 325 8 12345678 1 0 1
```

Two way:

```
C0 0 532.0 std1 slrd las1 tim1 lro
C1 0 las1 Nd-Yag 1064.0 10.0 100 200 20 1
C2 0 slrd MCP 532.0 8 1300 1 TTL 10 1.0 50 10 none
C3 0 tim1 TAC na MLRS na 0
C4 0 lro 100 5 325 8 12345678 1 0 1
```

7. Implementation Procedure

Implementation of the CRD format at the ranging station involves several steps,

- Choosing where to make changes in the station software to write the CRD format files (7.1)
- Making the changes (7.2)
- Testing the changes on site (7.2, 7.3)
- Submitting the old and CRD formatted data in parallel for testing (7.3)
- Discontinuing the old formats (7.3)

These issues and more will be addressed below.

7.1.Methods of implementation

There are several approaches that can be taken to implement the CRD format at a laser ranging station. Briefly they are as follows.

1)Record ranging data in the CRD format. Then the CRD format becomes the native format for the entire data system. This implies a great deal of work and the best chance to include all the new fields in the data. The difficulty of modifying and testing real-time ranging software may make this approach prohibitive. If the acquisition data format already has all the needed fields and precision for the CRD format, this approach is probably not necessary.

2) After ranging, convert the acquisition data files to the CRD format and proceed with calibration, filtering, normal pointing, and the like, using the CRD format as the native format. This takes less work than option 1), and insures that most or all of the new format features are incorporated in a natural way. As an example, this is the path chosen for MLRS. The reductions software suite was not written from scratch, but the read and write code in each was replaced with corresponding CRD routines, and some hitherto separate lunar and satellite laser ranging programs were consolidated into single programs.

3) Take old format normal points, full rate, etc. from the filtering and normal pointing system on site and convert to CRD-formatted file. Programs to convert old formats to the CRD format already exist in the sample code suite. This is quick and easy, but fails to take advantage of the new features of the format.

4) Some stations may use intermediate files or databases during data processing that already include all the the desired new fields and extended precision. For these stations, conversion to the CRD format may be as simple as creating a new back-end formatter that writes data in the CRD format rather than the old distribution format.

7.2.Software resources

As with the CPF implementation, there is a suite of sample code that can help in the CRD format conversion. This software is supplied “as is,” and there are no guarantees associated with it. The software has been tested with a limited amount of data, and there may still be errors and incomplete

implementation of the CRD standards. This software is meant to be a starting place for those implementing and managing ranging data in the CRD format. Any bug corrections or software enhancements would be welcomed by the authors.

The CRD sample software can be broken into several groups.

1) Code common to many applications

directory: common_c ('c' version)

directory: crd_rw_c

- read_crd.c - read and parse CRD records
- write_crd.c - write CRD records
- getfield.c - read unlimited data fields from a string

2) Code common to many applications

directory: common_f ('FORTRAN' version)

- read_crdf.f - read and parse CRD records
- write_crdf.f - write CRD records

3) CRD file checkers ('c' only).

directory: crd_chk_c

- crd_chk.c - check CRD file for errors
- crd_cstg_np_cmp - compare CRD and CSTG normal points from a single pass
- crd_merit_fr_cmp - compare CRD and MERIT II full rate data from a single pass

4) Various conversion utilities between CRD and older SLR/LLR formats ('c' only).

directory: crd_conv_slr_c

- crd_to_cstg_np.c - CRD normal points to old normal point format
- crd_to_cstg_ql.c - CRD sampled engineering to old
sampled engineering format
- crd_to_merit.c - CRD full rate to old fullrate format
- cstg_to_crd.c - Old normal point and sampled engineering
to CRD format
- merit_to_crd.c - Old full rate to CRD format
- read_cstg.c - Read old normal point and sampled engineering
records
- read_merit.c - Read old full rate records
- write_cstg.c - Write old normal point and sampled engineering
records
- write_merit.c - Write old full rate records

5) Various conversion utilities from old lunar format to CRD ('c' only).

directory: crd_conv_llr_c

- cllr_to_crd.c - Old COSPAR lunar to CRD format
- read_llr.c - Read old lunar format records
- cospar_llr.h - Header file with old lunar format information

6) Various CRD file split, merge, sort, and miscellaneous routines.

directory: crd_split_c

- | | |
|-------------------|---|
| crd_split.c | - Split multi-pass and multi-data-type file into separate files using station naming convention |
| frd_strip.c | - Strip out station-dependent (9x) records and remove some white space from CRD full rate file |
| merge_crd_daily.c | - merge single pass normal point, quick look, and full rate files into single day files. |

7) Various header and include files

directory: include ('c' and FORTRAN versions)

- | | |
|---------|---|
| crd.h | - Header file with CRD information ('c') |
| crd.inc | - Header file with CRD information (FORTRAN) |
| cstg.h | - Header file with old normal point and sampled engineering information |
| merit.h | - Header file with old full rate format information |

To compile this code on a Linux system, just type

`./make.sh`

on the command line.

In selected directories there are scripts to test the program using supplied data. Data files ending in ".ref" are the reference (or "correct") output from the conversion programs. To run the tests, and automatically compared results, type

`./test.sh`

in each of these directories. Any differences between the test and reference data files will be shown. Differences in dates in H1 records is normal, as this reflects the time of file creation.

7.3. CRD file testing procedures

Once software has been converted to produce CRD-formatted data files, the CRD files must be tested for compliance with the CRD format and consistency with the old format data. Three tools in the sample code suite can help. The first is `crd_chk`, which checks the CRD data file (full rate, sampled engineering, or normal point) for compliance with the format. There will be a report generated for each file breaking down the header into easily readable lines. The literal "err" will show data fields that are out of compliance. Other error messages will deal with such issues as out-of-sequence records, missing fields in records, and so forth. A tally of all record types is also provided.

`Crd_cstg_np_cmp` compares the CRD normal point against the old-format normal point for the same pass. Once again, a report is produced showing errors and tallying information on the pass. Flags that are not consistent between the 2 formats are noted. The number of extra normal points in each format are listed. Each of the major common data fields are compared for consistency, and differences are ranked according to size. The number of passes with a "perfect" match are listed first, followed by

those that probably differing due to round-off error. These 2 categories can be presumed to pass. Entries in the third and following levels need justification, as do differences in number of normal points. Some such differences may be due to filtering differences, and some to blunders in the code or data handling.

Crd_merit_fr_cmp compares the CRD full rate data against the old-format full rate data. It provides a report similar to that for crd_cstg_np_cmp, above.

When the station is satisfied that the CRD files it is producing are correct, their Operations Center should be contacted about submitting old format and CRD format data in parallel for some period of time.

The Operations Center will then use software similar to that described above to validate the data with respect to the CRD format and the old-format data. Passes that fail the tests will be sent back to the stations for further work. The goal of this step is to identify and correct (or explain) passes that could skew the precision orbit determination (pod) solutions.

When the Operations Center has validated the data to the best of its ability, two weeks of data will be submitted to various Analysis Centers for validation. Data for different target types may be sent to different AC's as required. The purpose of this step is to demonstrate that small differences in the data due to round off and filtering have no significant consequence to the pod solution.

After the AC's and OC's have been satisfied, the station will be notified and production of data files in the old format may cease.

Note: These procedures are preliminary and may change based upon experience.

8. Notes on new data fields

8.1. *Advantages to analysts*

While the introduction to this document contains a list of advantages of the CRD over previous formats what follows is a list of advantages the analysts will be most interested in.

1. Skew, Kurtosis, peak-mean are data fields that have been requested over the years but have not been available in the data set. This should allow analysis of over-filtering and anomalous data distributions.
2. The CRD format is capable of handling multi-channel, multi-stop, multi-color systems. Although the old formats could handle multiple color data, they could not be integrated into one normal point file. Multi-channel and multi-stop data is not explicitly recognized in the old formats.
3. Standard satellite, transponder, and lunar data can be fully represented in one format.
4. The free format data records mean the number of significant digits can be increased to the accuracy required by some missions without requiring all targets to carry additional digits.
5. Most station configuration information can now be embedded with the data. This can help with keeping track of station configurations at a finer granularity than the current SCH and SCI values. This will only help if stations use the new configuration section and if values are current. This is an area that many analysts will not be interested in, but the data is readily available for those who are.
6. The all-in-one, building-block nature of the format should make processing full-rate and other special formats easier, if they are needed. Also, full-rate files will be smaller than with the Merit II format.
7. Future enhancements to the format should not require starting over again.

8.2. *Record-by-record Information*

8.2.1. *Headers*

H1 – format header

- Date of file production (as distinct from release number in H4) tells when the current file was created (by the station, or the operations center merge or split programs, etc.). This could help verify that the latest file is available.

H2 – station header

- The station name may be more recognizable than the pad ID.

H3 – target header

- All 3 commonly used satellite IDs are included.
- Spacecraft epoch time scale is available for transponders
- Target type (passive satellite, passive lunar, transponder, mixed, etc.) will allow sending data to the right processing steps for the target

H4 – session header

- A flag tells whether this is full rate, normal point or sampled engineering data. This starts a data block for a particular station, satellite, and time span which ends with the next H8 record.
- Provides many of the fields in the Merit II formats – but watch the sense of the flags.

- Indicates whether this is 1 or 2 way ranging, etc. needed for processing decisions.
- Data quality alert will give some sense as to whether the data should be used in critical applications.

H8 – end of session/pass

H9 – end of file

8.2.2.Configuration

C0 – system configuration

- Provides wavelength and pointers to related configuration information for this wavelength.

C1 – laser configuration

- Various info including fire rate, pulse width, divergence, number of pulses.
- These could all be of interest in analysis.
- For example, does the pulse width match the rms of the calibrations and data?

C2 – detector configuration

- Contains detector information, such as detector type, quantum efficiency, spectral and spatial filters.
- The data biases and corrections may depend on the detector type, e.g. whether the detector is a cspad or mcp.
- Is the change of signal processing algorithm the reason for changes to this station's biases?

C3 – timing system configuration

- Is a new station bias correlated with changes to any of these pieces of equipment?

C4 – transponder/clock configuration

- This record is needed for transponder analysis where the spacecraft and ground station need to be merged, and both are running on separate clocks.

8.2.3.Data

10 – range record

- Variable precision in seconds of day and the return field allow for increased precision for transponders.
- Epoch event will tell how to interpret time of flight/receive time field, and allows for transponder data.
- Detector channel and stop number show where the data comes from. Each channel could have a separate bias.

11 - normal point

- Again, epoch event will tell how to interpret time of flight/receive time field, and allows for transponder data.
- Normal point window length gives the length in seconds, for those targets that require variable normal point lengths (lunar, satellites with highly elliptical orbits).
- Skew, kurtosis and peak-mean can show anomalies in the data distribution that would indicate hardware or processing problems. Since lasers do not produce Gaussian distributions, a skew that is unusually symmetrical could indicate over-filtering.
- Return rate could give some sense of system performance, tempered by sky conditions.

12 - range supplement

- Nothing new except time bias.

20 – meteorological record

- Origin of values specifies where the values came from (measured or interpolated value).

- 21 - meteorological supplement record
 - This contains various ancillary data that could correlate with return rate.
- 40 – Calibration record
 - Can include target system delays (transponder).
 - Number of fires and points used could indicate quality of calibration results.
 - Skew, kurtosis, and peak-mean are also included here.
- 50 – Session (pass) statistics record
 - Provides skew, kurtosis, and peak-mean for the entire pass.
- 60 – Compatibility record
 - Includes old system change indicator (SCH) and system configuration indicator (SCI) for those stations not including c1-c3 configuration records.
- 9x – user defined records
 - Not applicable. The analysts will normally not see these.
- 00 – comment record
 - If the station considers data suspect, or if there is anything unusual that is not covered in the configuration records, this record type can provide an explanation. These should be kept with the data.

9. Conclusion

The CRD format offers a number of improvements over the existing, separate normal point, sample engineering, and full rate data formats. Stimulating the development of the new format were the need for extended fire time precision and additional fields for transponder missions such as LRO and the need for reduced size for full rate data from high-repetition-rate laser systems. In order to satisfy these needs, to add functionality not previously seen, and to make provision for additional revisions in the future, the formats were redesigned and combined into a single format. The CRD format has features in common with the Consolidated Predictions Format (CPF) introduced earlier. The files are separated into headers records, data records, and, for the CRD format, configuration records. Each of these 3 sections has some records that are needed only for specific missions types or station capabilities, allowing a great deal of versatility. Care was taken to make the format compatible with the Engineering Data Format (EDF), and was developed with XML in mind.

The format was developed under the auspices of the ILRS Data Formats and Procedures Working Group. The authors would like to recognize the active participation and many contributions of the members of the DF&P WG and the world-wide laser ranging community and the support of NASA and EOS.

Appendix A.Resources

The official list of satellite names and numerical identifiers can be found at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/satellite_names.html.

The satellite numerical identifiers can be found at:

http://ilrs.gsfc.nasa.gov/satellite_missions/list_of_satellites/index.html.

The official list of station names can be found in the “Code” column at:

<http://ilrs.gsfc.nasa.gov/stations/sitelist/index.html>.

The official list of station monument (pad) numbers and codes can be found at:

<http://ilrs.gsfc.nasa.gov/stations/sitelist/index.html>.

Find information on site files at:

http://ilrs.gsfc.nasa.gov/stations/site_procedures/site_logs/site_log_procedure.html.

Find formats for the pre-CRD data formats at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/np_format.html

and

http://ilrs.gsfc.nasa.gov/products_formats_procedures/fullrate/fr_format_v3.html.

The latest official version of this document can be found at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/crd.html.

Test data can be found at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/crd.html.

CRD Sample Code (format converters and check programs) can be found at:

http://ilrs.gsfc.nasa.gov/products_formats_procedures/crd.html.

Appendix B.Common Abbreviations

CRD	Consolidated laser Ranging Data Format
COSPAR	Committee on Space Research, a Committee of ICSU, the International Council for Science.
CPF	Consolidated laser ranging Prediction Format
FWHM	Full width at Half Maximum, relating to pulse width
ILRS	International Laser Ranging Service
LLR	Lunar Laser Ranging
LRO	Lunar Reconnaissance Orbiter
ND	Neutral Density, which describes opacity of a broad band optical filter.
NORAD	The North American Aerospace Defense Command
ns	nanoseconds
ps	picoseconds
RMS	Root Mean Square. Same as standard deviation.
SLR	Satellite Laser Ranging
SCH	Station Change Indicator
SCI	Station Configuration Indicator
SIC	Satellite Identification Code, a 4 digit satellite descriptor.
SRP	System Reference Point, usually described as the first non-moving point in the telescope light path.
us	microseconds
UTC	Coordinated Universal Time, formerly known as Greenwich Mean Time (GMT).
XML	eXtensible Markup Language.